RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting [6]

Effect of RF Power Output Levels on Unit Cost

Presented by Tom Mosher, UPS AT

SUMMARY
This paper presents an analysis of the impact on unit cost due to the RF output power requirements for equipment categories (A0, A1, A2, A3). This paper addresses Action Item 5-9.

Introduction:

This paper addresses UAT MOPS Action Item 5-9 ("Differences in cost as power levels increase or decrease on A0-A3 equipage classes"). The power levels proposed in Draft 2 of Section 2.1 (UAT-WP-3-04) are presented in the form of gain block diagrams. The PA lineups are presented along with Cost and Size factors for each alternative. The Cost and Size factors allow the reader some insight into the impact on system cost and physical size of the various power output options.

Some additional configurations are presented where the analysis reveals a minimal impact on cost or size.

RF Gain Blocks:

The table below contains some typical RF power transistor performance data. The reader is cautioned that the RF power transistor market is a very volatile one. Parts appear and disappear from the market with alarming regularity. The MOPS committee should guard against relying on availability of any specific parts. The performance figures are typical for 1,000 MHz operation.

Cost and Scale Factors:

Each type of gain block is assigned a Cost Factor. The unity cost factor is assigned to the Vehicle Transmitter configuration (1 watt of transmitter output power). Cost Factors for all other configurations are determined by adding the Cost Factors of the various component pieces. The Cost Factors for the typical gain block performance are shown below. The table provides a range of the combinations available, but is not an exhaustive list.

Similarly, each gain block is assigned a Size Factor. It is anticipated that the power amplifier will be constructed on a substrate of controlled dielectric properties (e.g. Teflon), and will make use of strip-line techniques to form some of the circuit elements. The characteristics of the gain block have a substantial impact on the amount of substrate area required. The Size Factors are normalized to 1 square inch of surface area.

Table 1 - Typical RF Power Transistor Performance

Pin	Pout	Gain	Cost Factor	Size Factor
0.4 W	10 W	14 dB	3	3
1 W	15 W	12 dB	3	3
2 W	20 W	10 dB	3	3
1.25 W	25 W	13 dB	12	6
3.5 W	50 W	11.5 dB	12	6
6.0 W	60 W	10 dB	12	6

Summary of the configurations:

Each of the presented configurations are briefly described in the following sections. These configurations should serve as guidelines only. There are additional minor loss factors which are not accounted for in the gain diagrams. Also, antenna switching circuitry is not shown. Please refer to the two pages of diagrams attached.

Vehicle Transmitter:

The Vehicle Transmitter is the baseline configuration. The transmitter provides 1 watt of RF power for use either as the transmitter output (0.5 watts at the antenna), or as the exciter stage for the higher power categories.

Low Power ADS-B

This configuration adds a 10 dB gain stage to generate a 10 watt RF output. The –3 dB feedline reduces the power to 5 watts at the antenna.

An important aspect of this power category is that it is achieved with the use of two low-cost and small devices. This allows for the possibility that this configuration could be mounted within the aircraft control panel. Panel-mounting the UAT lowers the overall system cost by helping to reduce the installation and certification costs.

On the second page of diagrams, an alternative configuration is presented that increases the transmitted signal without increasing the equipment cost. A 1 dB increase in transmitter output power is identified, and the feedline loss is reduced from 3 dB to 2 dB. On an A0 aircraft, it is likely that 2 dB of feedline loss can be achieved economically due to the small size of the airframe. For example, 15 feet of RG-400 coax (cost about $1.50 per foot) gives 2 dB of loss. If more length is needed, a higher cost low-loss coax can be used without greatly increasing the installation cost. The overall result of this configuration is a 2 dB increase in transmitted signal, and a 1 dB increase in receiver sensitivity.

Medium Power ADS-B

This configuration requires an additional stage of amplification in order to reach 25 watts transmitter output, After the –3 dB feedline, there is 12.5 watts present at the antenna. Because of the use of 3 amplifier stages, and the higher cost of the power transistor, this configuration costs 4 times the low-power unit, and occupies 2.5 times more space.

On the second page of the drawings, an alternative configuration is presented. By adjusting the level of gain used by each stage, a 3dB increase in transmitter power is achieved without increasing the component costs. There is no effect on the amplifier module size. However, the change in the gain lineup may cause increased manufacturing costs, because the 2nd gain stage is no longer identical to the Low Power configuration.

High Power ADS-B

Due to the lack of suitable RF power transistors, multiple devices must be driven in parallel in order to achieve the 200 watt transmitter output, or 100 watts at the antenna. The cost of this configuration is over 4 times that of the Medium Power category, and occupies about 4 times the circuit area. There are additional cost factors due to the requirement for splitter and combiner circuitry to drive the parallel power devices.

The maximum power available from the highest power transistor studied is 60 watts. Even if 4 of these were perfectly combined, there would be only 0.8 dB of margin above the 200 watt transmitter output requirement. Internal losses from combiner and antenna switching networks (not shown) would certainly exceed this margin. In fact, it is likely that at least 5 gain stages would need to be combined, or an alternate amplifier technology would need to be investigated.

This configuration presents a serious challenge in design, packaging, and cost.

Other configurations

The reader can use the data presented and these examples to evaluate other combinations of gain blocks. Keep in mind the input power requirements for each gain block. High power RF transistors have a limited gain range before reaching compression. Consequently, overdriving the input does not result in corresponding levels of output power. RF power transistors that are suitable for the UAT signal format do not exist at this time at greater output levels than 60 watts.

Other Gain Sources:

The transmitter power requirements are a critical factor in the cost of the equipment, as well as the packaging and installation options available. If higher output power levels than those presented here are needed, some additional transmitter power gains may be available through the use of higher gain omnidirectional antennas (i.e. 5/8 wave vertical). This would increase the receiver gain at no cost, and allow for lower cost transmitter design.

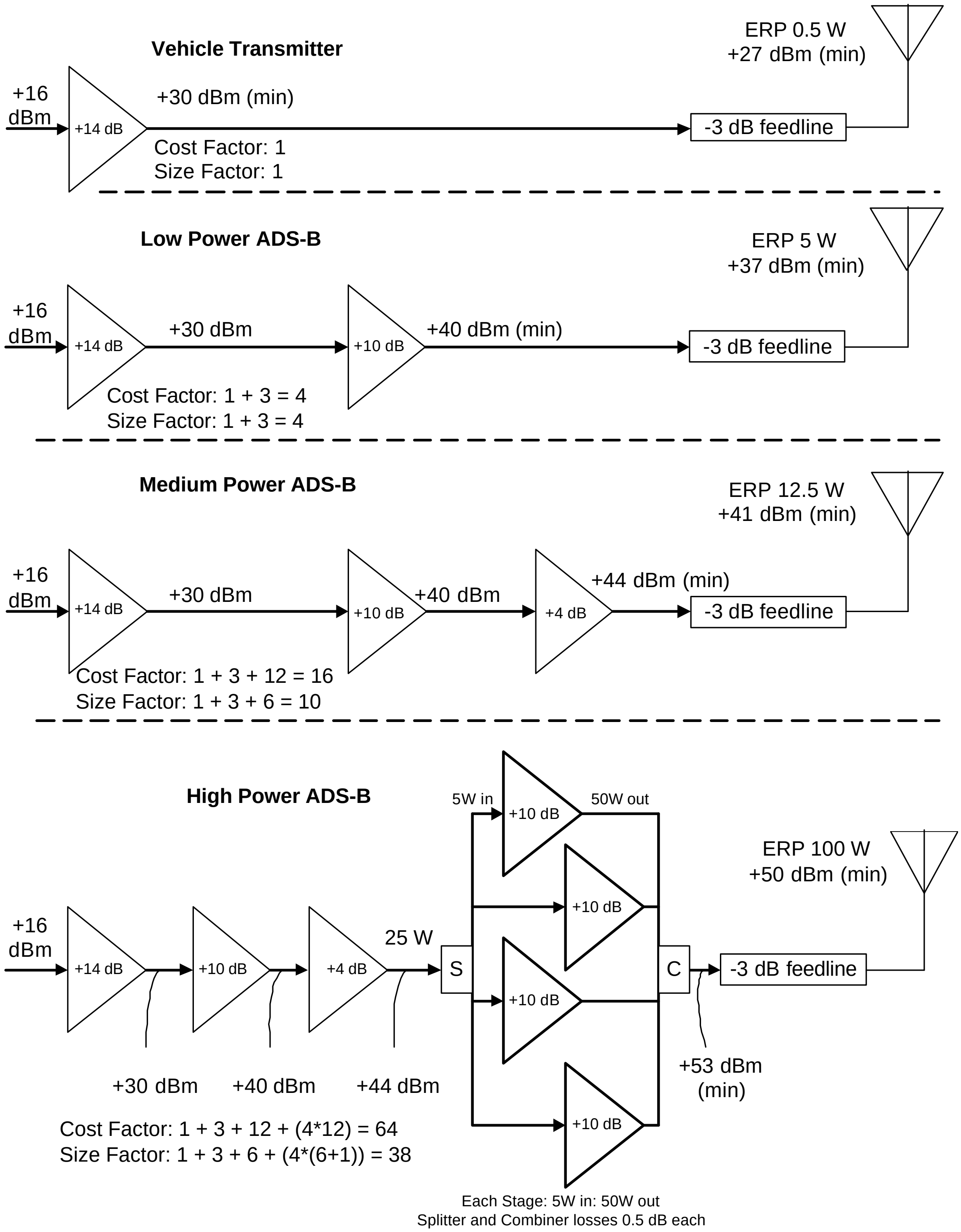
Allowing for perhaps 2 dB of additional antenna gain on both transmit and receive would go a long way toward easing the challenges of the High Power category. The 200 watt transmitter output could be reduced to 80 watts with no loss of link margin.

Final Thoughts:

Equipment and installation cost is a primary factor in achieving a high degree of UAT equipage across all aircraft. The MOPS committee should make every effort to evaluate the UAT requirements such that the benefit of ADS-B is available to all airspace users.

The total aircraft population (FAA and AOPA estimates) is about 226,000, with 206,000 (over 90%) GA aircraft registered. It is important to maximize the GA equipage with ADS-B capability.

UAT Transmit Power Categories - PA lineups and Cost Factors



UAT Transmit Power Categories - PA lineups and Cost Factors - Page 2
Alternate Configurations for Low and Medium Power Levels